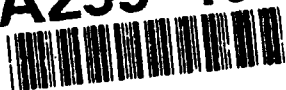FINAL REPORT

OFFICE OF NAVAL RESEARCH CONTRACT # N00014-87-K-0317

entitled

INTERMITTENCY IN TURBULENT MARINE BOUNDARY LAYERS:
SIGNIFICANCE TO COLONIZATION OF SURFACES BY LARVAE

by

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RESEARCH GOALS:

Our goals have been to assess some of the mechanisms by which hydrodynamic processes in turbulent boundary layers affect rates of colonization of surfaces by planktonic larvae of diverse benthic invertebrates. More specifically, we have worked to determine the extent to which the spatial and temporal nature of turbulence affects the supply of larvae to a surface and the advection (removal) of larvae from a surface, once it is contacted.

SPECIFIC OBJECTIVES:

To understand the effects of particle settling and turbulent mixing on rates of supply of larvae to surfaces. Also, to understand effects of turbulent drag forces (imposed by fluid shear) on probabilities of retention of larvae on surfaces, once they are contacted. We have assessed the influence of time of contact on the attachment strengths of larvae to a surface.

APPROACH:

Regarding larval supply, a numerical, advection-diffusion model was developed that predicts effects of particle settling and turbulent mixing on rates of supply of larvae to surfaces that vary in roughness. Regarding larval retention, we have used controlled flume flows to assess fluid shears required to remove larvae exploring or attached to the flume bottom. Under these controlled laboratory conditions we have determined the extent to which fluid shears resulting in larval removal depend on the time during which larvae were in contact with the flume bottom.

TASKS COMPLETED:

We have published a version of our numerical, advection-diffusion model of larval supply to potential settlement sites (Eckman, J.E. 1990. A model of passive settlement by planktonic larvae onto bottoms of differing roughness. Limnology & Oceanography. 35: 887-901)

We have published results of flume experiments using cyprid larvae of Balanus amphitrite that assessed the influence of shear and duration of antennular contact on retention of cyprids on smooth, plexiglass surfaces (Eckman, J.E., W.B. Savidge and T.F. Gross. Relationship between duration of cyprid attachment and drag forces associated with detachment of Balanus amphitrite cyprids. Mar. Biol. 107: 111-118).

SCIENTIFIC RESULTS:

The model of larval settlement predicts that rates of settlement of larvae should increase monotonically with the density of roughness features that dominate seafloor topography. Relatively flat bottoms should experience rates of settlement 2 - 4 times higher than bottoms with low densities of roughness features, but 1 - 2 orders of magnitude lower than bottoms with high densities of roughness. Whereas roughness density defines the direction of differences in settlement expected, the degree or intensity of differences is affected also by the height of roughness features, larval fall velocity and

shear velocity.

In flume experiments using <u>Balanus amphitrite</u> cyprids, drag forces associated with detachment were significantly and positively correlated with time of attachment, within the range 0 - 500 s, for 6 of 12 sets of measurements obtained on separate dates. In general, the instantaneous drag force at detachment was more strongly correlated with duration of attachment than was either the maximum or mean force exerted prior to detachment. Our indirect method of estimating drag forces from shear velocities measured < 0.5 cm from cyprids probably underestimated the true association between detachment force and attachment time, because the spatial coherence of shear velocities in the flume was not strong at these scales. The demonstrated relationship between attachment time and drag force at detachment suggests that spatial and temporal variability in fluid forces <u>in situ</u> may contribute to stochastic variations in intensities of settlement of <u>B. amphitrite</u>. Stresses sustained by the antennular adhesive of cyprids of <u>B. amphitrite</u> were an order of magnitude lower than those reported previously for <u>Semibalanus balanoides</u>. This difference may reflect differences between shear stresses (as measured in our experiments) and normal stresses (measured previously) sustainable by the adhesive secreted onto antennular pads. Alternatively, there may be interspecific differences in the adhesive used for reversible attachment or in behavioral responses of exploring cyprids to strong flow.

ACCOMPLISHMENTS:

The model we developed for the first time offers a means of predicting quantitatively and a priori rates of transport of larvae to potential settlement sites. Our flume studies are the first to examine larval exploration and settlement within a short-period temporal frame, and should therefore are leading to new insights regarding the influence of temporally variable hydrodynamic forces on larval settlement.

INDEX OF PUBLICATIONS:

Eckman, J.E. 1990. A model of passive settlement by planktonic larvae onto bottoms of differing roughness. Limnology & Oceanography. 35: 887-901.

Eckman, J.E., W.B. Savidge and T.F. Gross. Relationship between duration of cyprid attachment and drag forces associated with detachment of <u>Balanus amphitrite</u> cyprids. Marine Biology 107: 111-118.

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